



HVOF Coatings at Hill AFB



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■ AGENDA

- Design Allowables From A-10 Piston Testing
- On-Going Investigations for landing gear applications
 - Duplex Coatings
 - Coating Adherence After Repair Processes
 - Liquid Nitrogen Exposure(Shrink Fits)
 - 375F Bake(Hydrogen Release)
 - Diamond Grinding of 300M Substrate
- Implementation at Hill AFB

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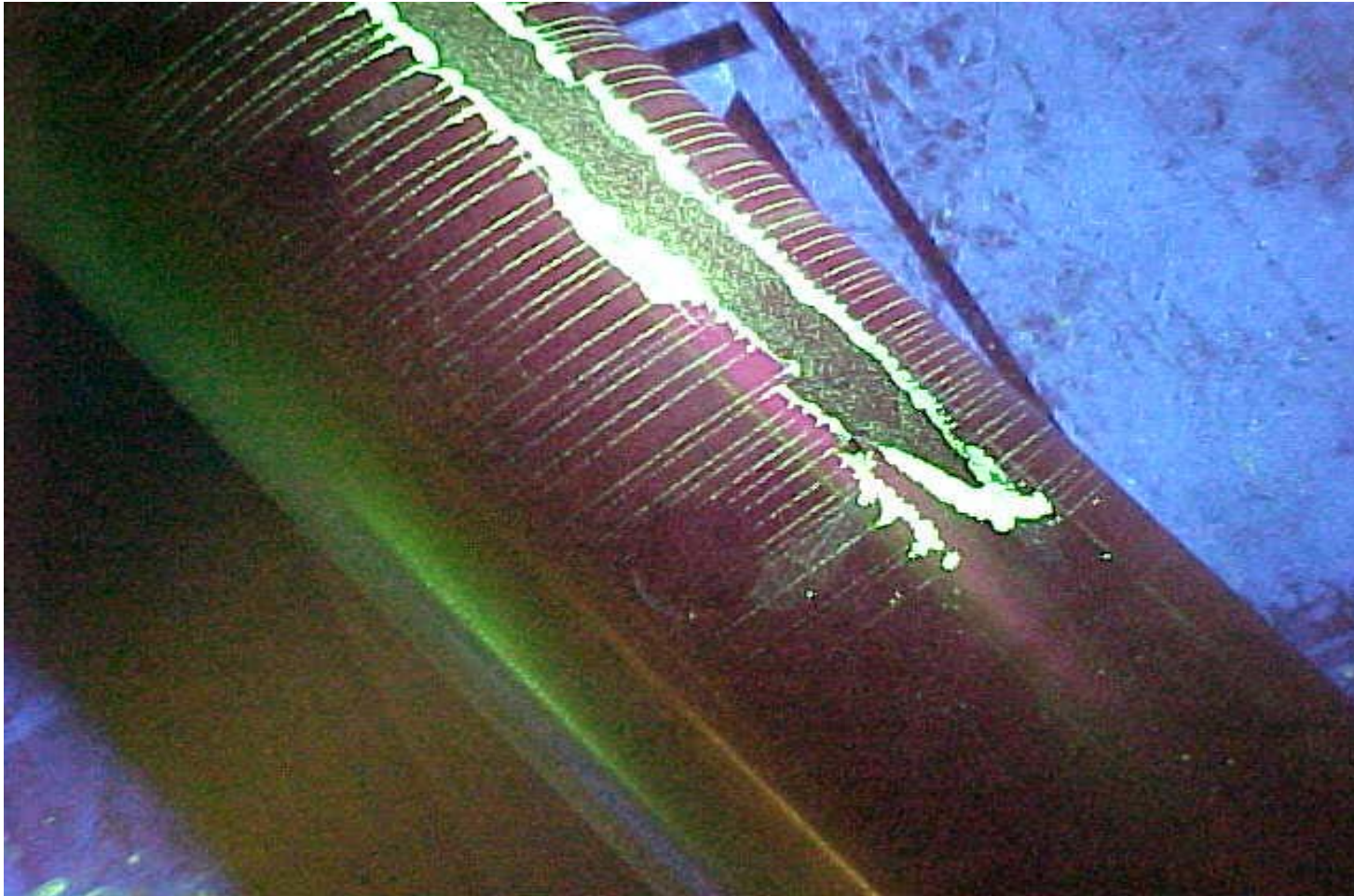
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Appearance of Cracks in Coating and Spalled Zone



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Coating Integrity Testing Summary



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- **Piston test program(coated with WC-17%Co)**
 - Thick coatings(.010 and .015 inches)
 - Simulated high bending stress conditions
 - Typically 200 cycles above 180 ksi outer fiber bending stress
 - Testing conducted until spallation of coating
 - Spallation occurs near 240 ksi for 0.010 inch thick coating (R= -.33)
- **Air Force landing gear fatigue spectrums have been reviewed(in progress)**
 - Cycles to 180-200 ksi only 30-40 out of 8000 cycles (1 lifetime)
- **Conclusion: HVOF coatings will not spall**
 - Based on bend test results
 - Based on fatigue spectrums reviewed to date



WC-17%Co Coating Design Allowables



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R ratio: [Stress Min./ Stress Max.]	Coating Thickness (as-ground)	Allowable Bending Stress: (Mc/l)	Allowable Strain
-0.33	0.010 inches	240 ksi	0.8%
-0.33	0.015 inches	190 ksi	0.67%
-0.41	0.010 inches	240 ksi	0.8%
-0.47	0.010 inches	240 ksi	0.8%
-1.0	0.010 inches	200ksi	0.7%

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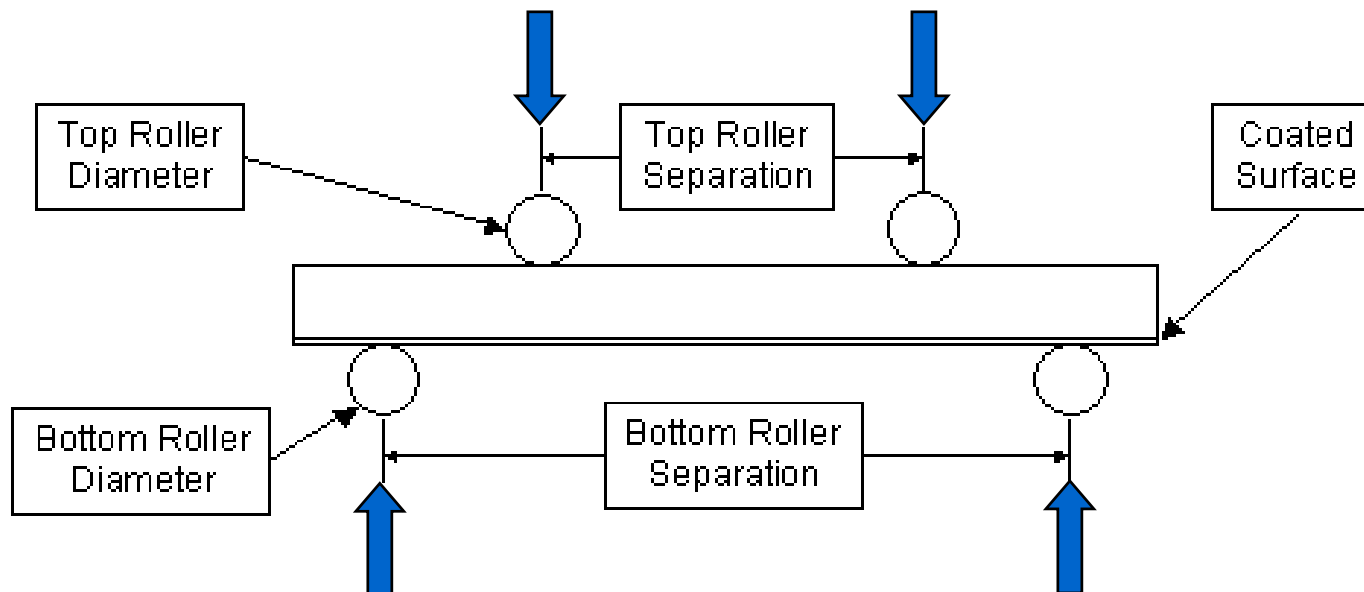


HVOF Duplex Coatings

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■ Monotonic Testing of Duplex coatings

- Working with Praxair Surface Technologies (Dr. Daming Wang) to investigate duplex coatings for thick build-up repair of landing gear components
- Using 4-pt bend beams(300M) to study strain to fracture and spallation



4-Point Bend Test Schematic



HVOF Duplex Coatings



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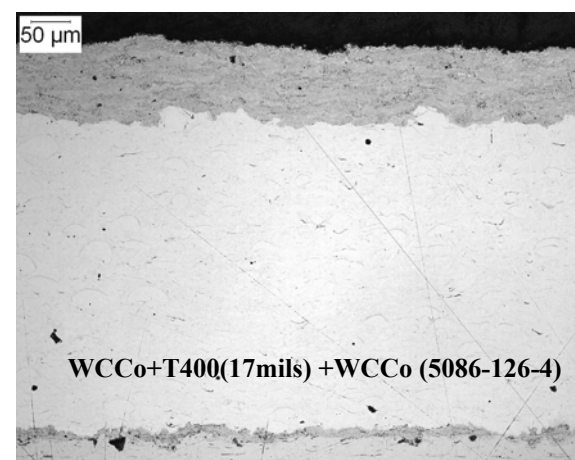
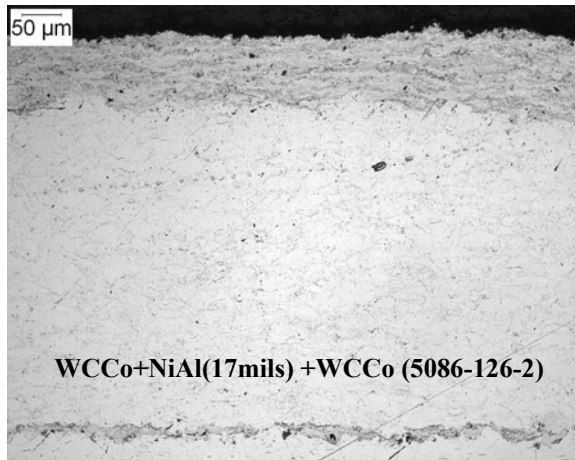
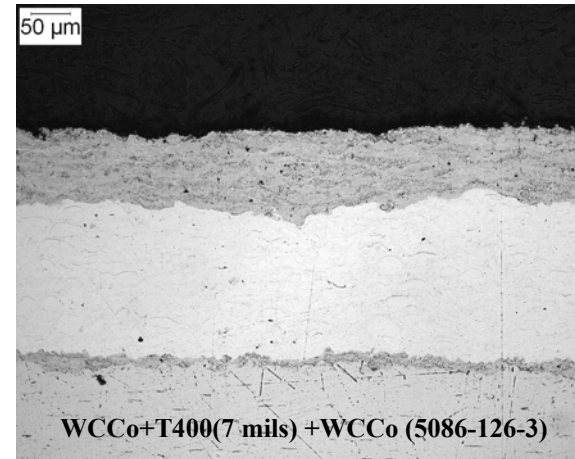
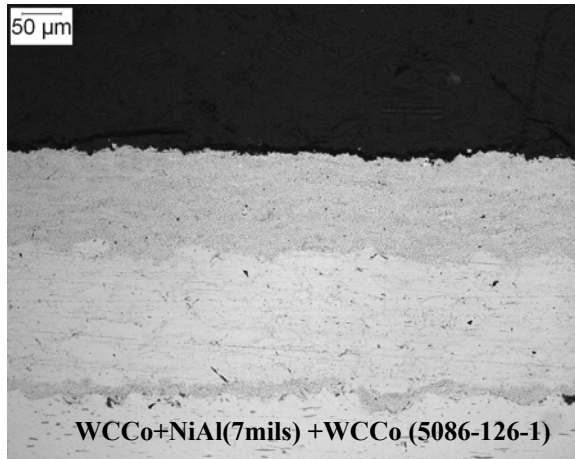
- **Coatings applied via HVOF process on 300M bar**
 - **Replacement for sulfamate nickel build-up and cap with chrome plating**
 - **Bond coat(WC-17%Co)**
 - **Build-up coat(Ni-5%Al and T-400 investigated)**
 - **Topcoat(WC-17%Co)**
- **Benefits**
 - **No surface prep required after each coating application**
 - **One booth, Two powder feeders**
- **Investigating local(patch) repair**



HVOF Duplex Coating Microstructure



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HVOF Duplex Coating Bend Test Results



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4 pt Bar Material	Bond Coat	Build-up Coat Sprayed via HVOF process	Topcoat	Spalling near Yield Strength of 300M (230 ksi)???
300M (280-300 ksi)	None	None	WC-17%Co thickness .010	Yes
300M	WC-17%Co thickness .0005-.001	Ni-5%Al thickness .006-.008	WC-17%Co thickness .003-.004 Duplex thickness .010	No
300M	WC-17%Co thickness .0005-.001	Ni-5%Al thickness .016-.018	WC-17%Co thickness .003-.004 Duplex thickness .020	No
300M	WC-17%Co thickness .0005-.001	T-400 thickness .006-.008	WC-17%Co thickness .003-.004 Duplex thickness .010	No
300M	WC-17%Co thickness .0005-.001	T-400 thickness .016-.018	WC-17%Co thickness .003-.004 Duplex thickness .020	Yes

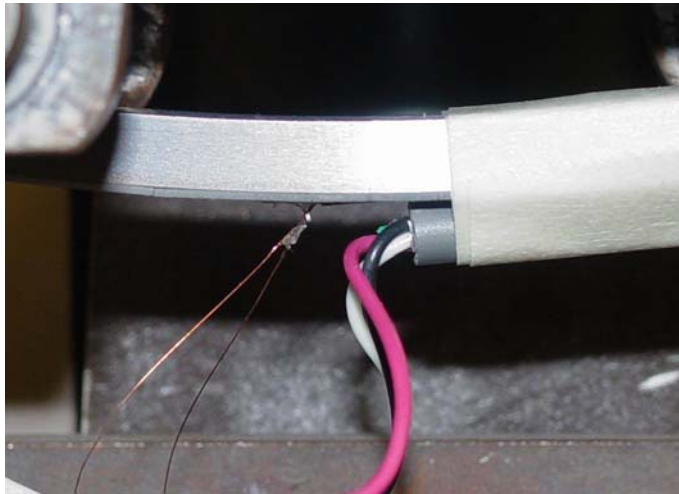
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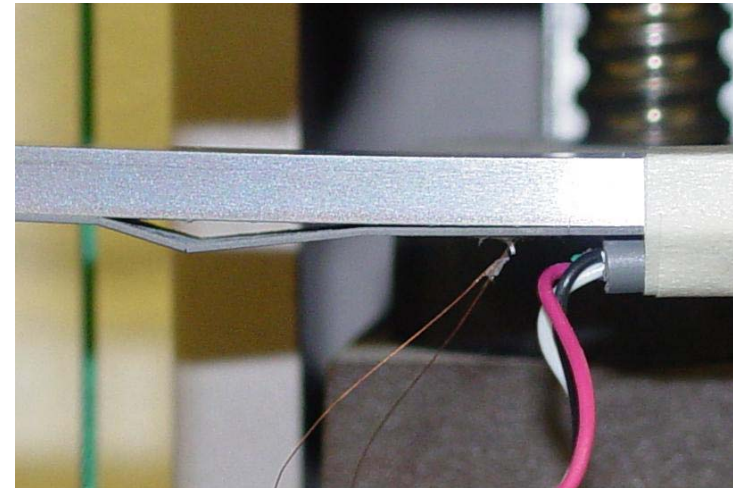
Spalling of Thick Duplex Coating



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Detection of Spallation Initiation
During Loading



Spallation When Load is Removed

WC17Co+T400+WC17Co (0.020")
(1343VM+CO109-7+1343VM)

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4-Point Bend Test Specimens with Duplex Coating Systems



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WC17Co+Ni5Al+WC17Co
(1343VM+NI-356-7+1343VM)



WC17Co+T400+WC17Co
(1343VM+CO109-7+1343VM)



Test Findings for Duplex Coatings



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- **Significant improvement using duplex coating system**
 - **Spalling resistance increase**
 - **Applied bending stress above Yield Strength**
 - **Substantial permanent deformation observed in bars after test**
 - **Crack indications observed in top coat**
 - Investigation on-going
 - **Ni-5%Al appears to be the winner for build-up coat**
 - Deposition efficiency higher than WC-17%Co
 - Lower powder cost
 - Weighs less than WC-17%Co
 - Can be sprayed via HVOF process(1 booth set-up)
 - No surface prep required between coating processes
- **Further investigation being conducted on duplex coatings**
 - **Local (patch) repair**
 - **Fatigue testing**



Recent Findings and On-Going Work



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- **Coating adherence following standard thermal processes**
 - **Liquid nitrogen testing**
 - Fatigue bar placed in liquid nitrogen
 - Bar tested at 190 ksi, R= -.33
 - No detrimental effects
 - **Hydrogen bake out cycle(375F)**
 - Fatigue bar exposed to two 24 hr bake cycles at 375F
 - Bar tested at 190 ksi, R= -.33
 - No detrimental effects
- **Diamond grinding of 300M steel**
 - **Study conducted with Heroux Devtek**
 - After 0.005 inches of material removal
 - Barkhausen inspection; no defects
 - Diamond wheel dressing with Alumina sticks
 - Total material removed 0.030 inches
 - Nital etch; no defects
 - Investigating diamond grinding of chrome plating



Implementation at Hill AFB



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- **Masking/fixtures challenge**
 - **Hard masking, only option???**
- **Grinding concerns**
 - **Changing wheels from Al-Oxide to Diamond**
 - Downtime to swap out wheels
- **No specs for spraying and grinding(AMS)**
 - **Hill has developed in-house specifications**
 - Allow tech order changes immediately



Implementation at Hill AFB



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- **Landing gear components approved for HVOF coating at Hill AFB**
 - **A-10 MLG Piston Barrel**
 - **A-10 NLG Piston Barrel**
 - **B-1 MLG Axle Journals**
 - **C-130 MLG Piston Barrel**
 - **KC-135 NLG Piston Barrel**
 - **KC-135 MLG Piston Barrel**
 - **C-5 MLG Roll Pin Journals**
 - **C-5 MLG Ball Screw Journal**
 - **C-5 MLG Outer Pitch Cylinder**
 - **F-15 Drive Keys**
 - **KC-135 MLG Axle Journals**